



Integrating Human Factors into Crew Exploration Vehicle (CEV) Design

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Background/ Purpose

- NASA's new Vision for Exploration
 - Send humans beyond Earth orbit
- It is critical to consider the human as a system
 - Demand early and continuous user involvement
 - Iterative “prototype/test/redesign” process
 - Cost savings since human/system issues identified early
- NASA/Prime Contractor human engineering (HE) team formed for Crew Exploration Vehicle (CEV)
 - Apply HE requirements and guidelines to hardware/software
 - Provide HE design, analysis and evaluation of crew interfaces

- Requirements development
- Mission-level task analysis
- Many practice-orientated evaluations using low-fidelity CEV mock-ups:
 - Crew module internal layout in terms of seats, display and control panel and other systems/ sub-systems
 - Window size and location
 - Validation of HE requirement on Net Habitable Volume (NHV)

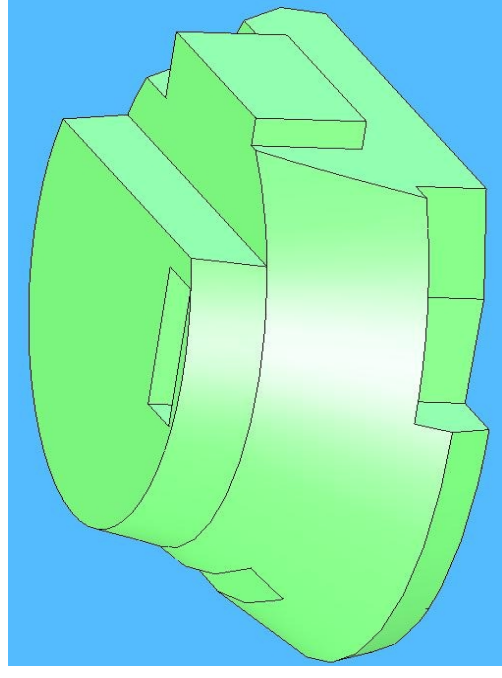
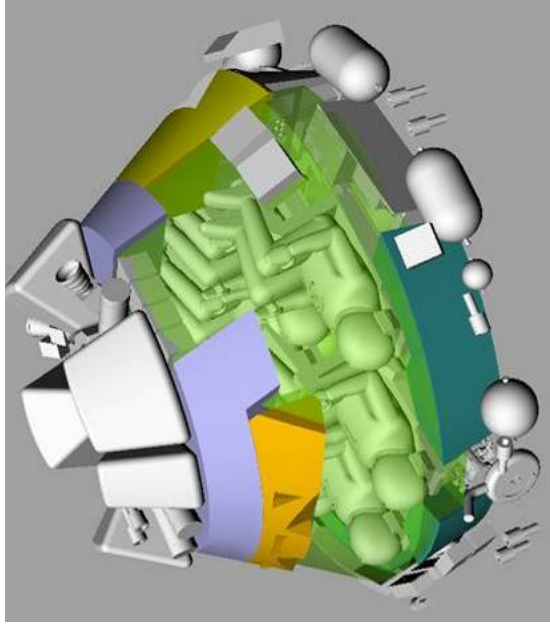
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- Definition of Net Habitable Volume (NHV):

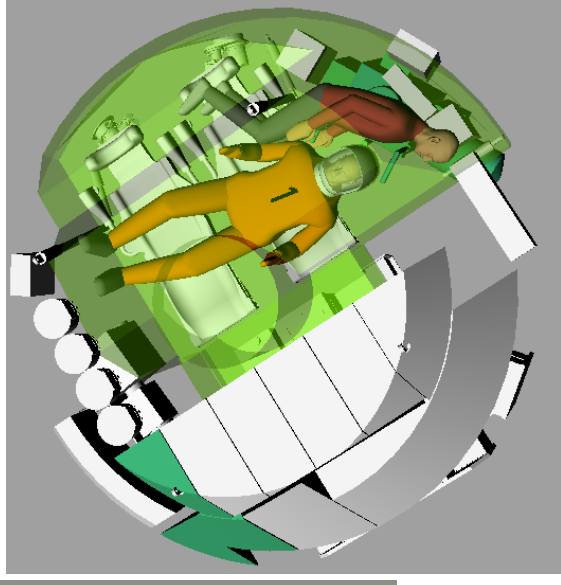
“Total remaining pressurized volume available to on-orbit crew after accounting for the loss of volume due to deployed hardware and structural inefficiencies which decrease functional volume.”

- Purpose of the Study:

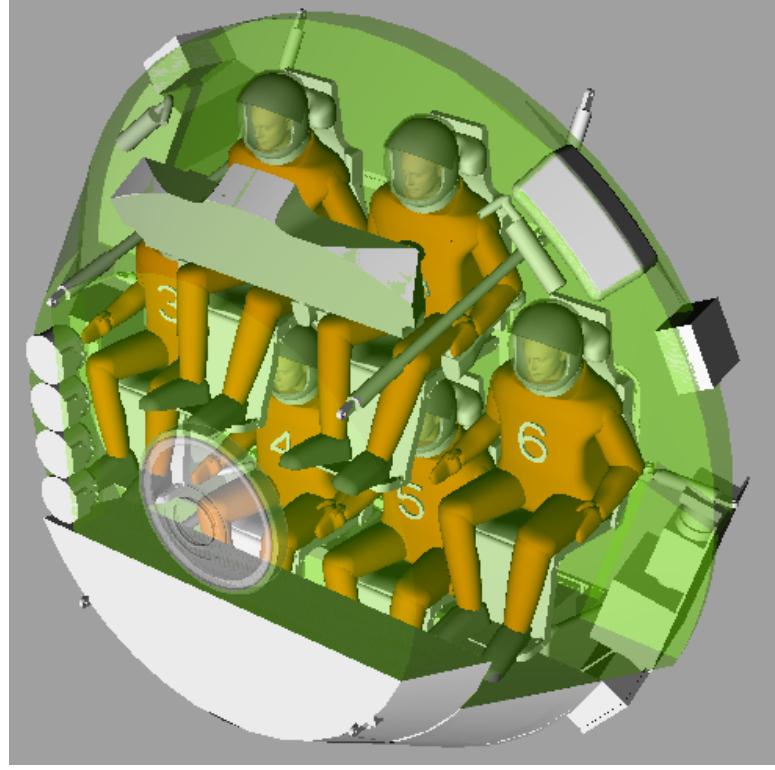
- Develop and validate requirements providing sufficient CEV NHV for crewmembers to live and perform tasks in support of mission goals
- Develop a standard NHV calculation method using computer models and physical mockups
- Measure and validate sufficiency of NHV for the current design concepts via computer modeling and crew/ stakeholder evaluations



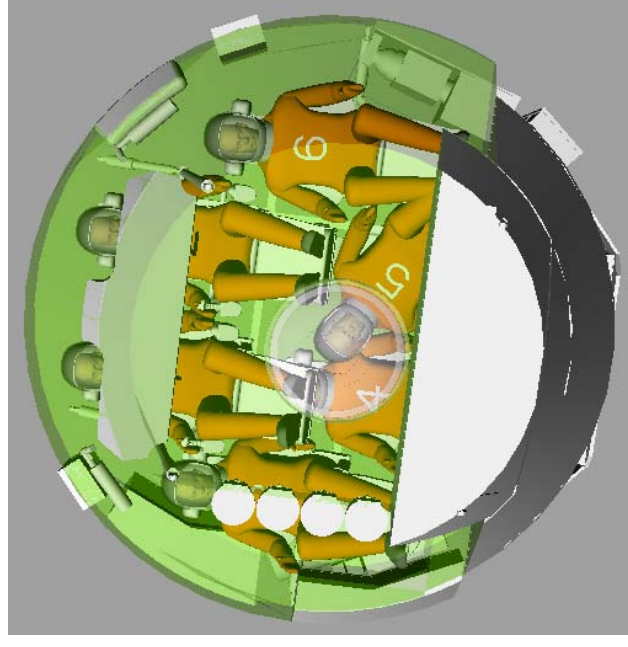
- Crew of 2, 4 and 6
 - Worst case: all 99th percentile male astronauts
- Selected critical on-orbit tasks such as:
 - Ascent/descent
 - Post insertion activities
 - Seat egress
 - Suit doff and stow
 - Waste hygiene usage
 - Sleeping/ eating
 - Cargo transfer
 - Docking/rendezvous



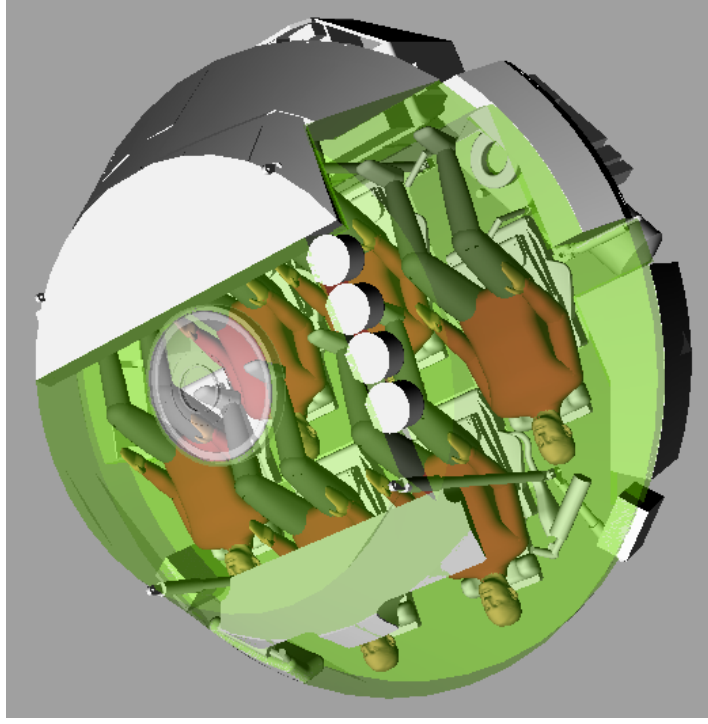
Ascent / Descent – Crew is suited and seats are in the full upright position.



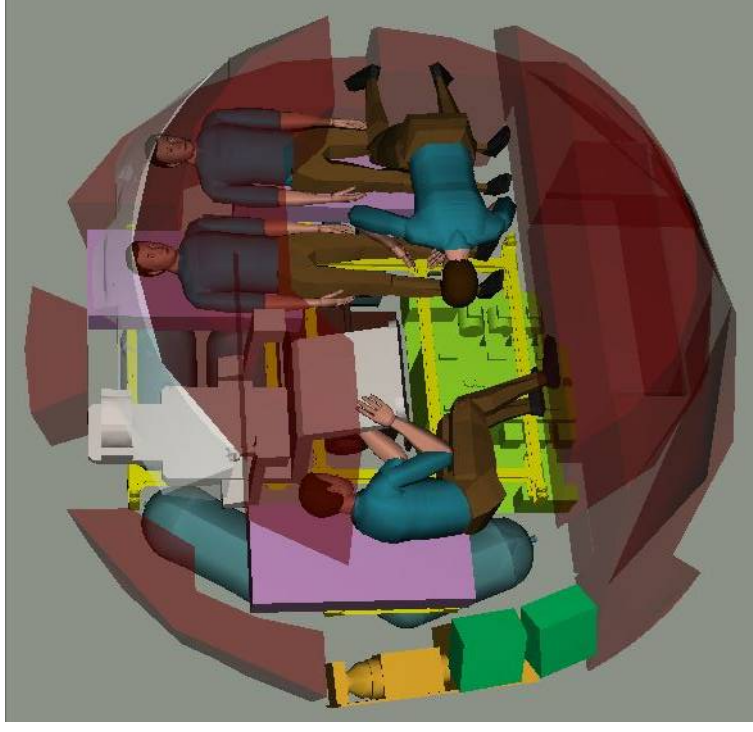
Rendezvous/ Docking – It is assumed that a crew member will adjust their position to allow for visibility through the hatch window to assist rendezvous and docking operations.



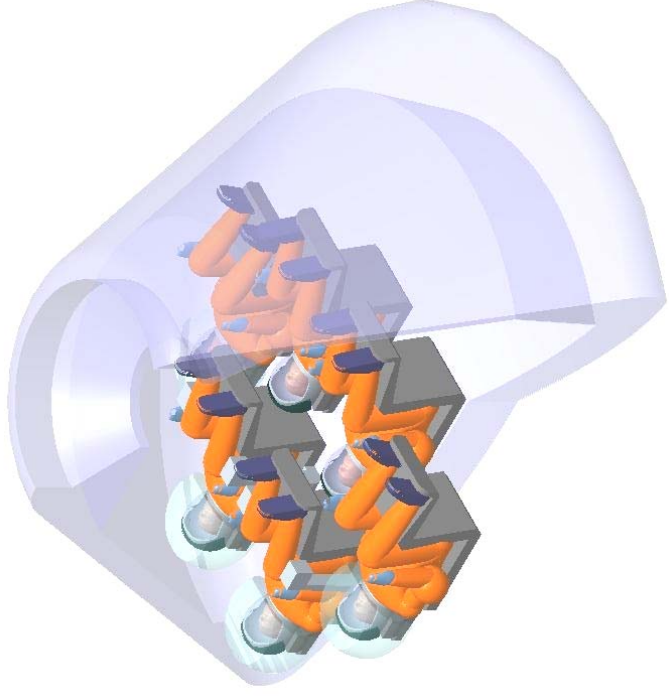
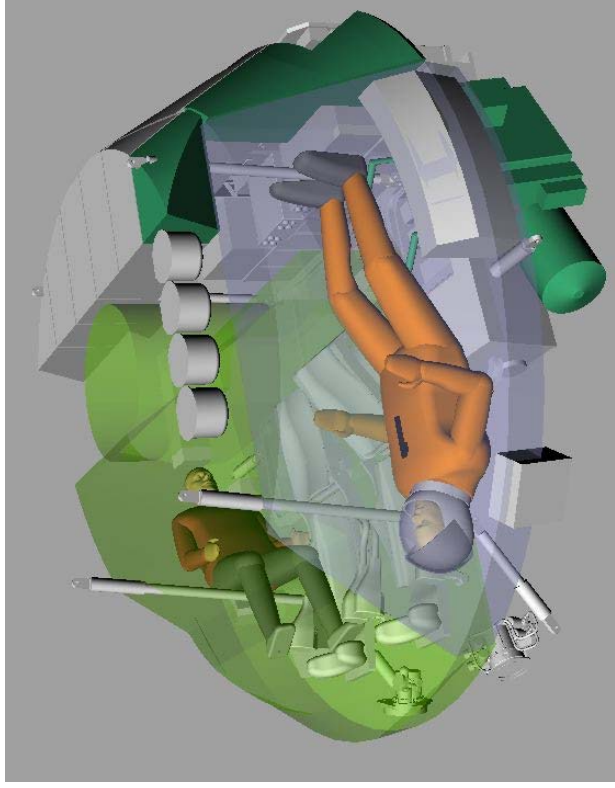
Post Insertion – All crew members have stowed their respective seats and suits. Access to waste and hygiene is now possible and the crew is ready to perform in-flight tasks.



Post Sleep – Potential activities include food preparation, review flight plan/execute pack, housekeeping/filter cleaning, and personal hygiene.



- Computer modeling analysis confirmed that there was adequate volume for unsuited scenarios and suit donning/doffing activity
 - Seats, suit design stowage and waste hygiene activities noted to be critical volume drivers





CASE STUDY: Human-in-the-Loop Evaluation Approach

Crew Exploration Vehicle (CEV)

- Participants:
 - Nine stakeholders and ten crewmembers participated in the unsuited evaluations
 - Six crewmembers also participated in a suited evaluation
- A physical mock-up was outfitted with volumetric representations of systems such as seats, and stowage bags
 - Design for suits, seats and other key systems do not yet exist for CEV
 - Notional placeholders such as existing space suit and seat prototype concepts were used in the mock-up
- Thirteen scenarios were developed to represent mission/crew tasks and considered to be primary volume drivers for the CEV
 - Unsuited evaluations included a structured walkthrough of these tasks such as suit stowage, waste hygiene activity, trash stowage, sleep, and 36-hour rescue (land/water)
 - Suited evaluations included timed donning of the existing launch and entry suit to simulate a contingency scenario followed by doffing/ stowing of the suits
- All mockup evaluations were videotaped
- Structured questionnaires were used to document user interface issues and impacts of layout configuration on volume

- Initial evaluation showed that NHV would support crew of 6
- NHV of the current design accommodated task-based scenarios evaluated



- Current design NHV accommodated space suit donning for a crew of 6
 - One should plan for volume of a minimum 2 crew helpers and 1 crewmember being donned in one volume area
 - Doffing → Only limitation was that a crewmember needed his/her full body length to doff the suit



- Human-in-the-loop evaluations also confirmed that there was adequate volume for unsuited scenarios and suit donning/doffing activity
- Additional comments from crew and stakeholders on internal cabin layout:
 - Seats → provide stowage volume for gloves, personal items & possibly the suit
 - Suit Stowage → stow individually and possibly integrate it into seat
 - Consumables → Multiple means of access to consumable stowage volume (e.g., access from side and below stowage volume)
 - Sleep → Simplified (shuttle) bag with less volume/weight; need to access to toilet
 - Restraints → Egress/Ingress handholds/footholds by hatch/tunnel, mobility aids for crewmember during seat egress in 1g, flexible straps for temporary stowage and mobility aids
 - Rescue-water landing → Sick bags/water should be handy

- In 2007, NASA and Lockheed Martin will conduct additional NHV studies of the most recent CEV design configuration(s) as the design matures
 - Computer modeling and analyses
 - Physical measurements of mockup hardware
 - Human in the loop task evaluations
- Based on these studies, verification methods for the NHV requirement will be planned and documented
 - Master Verification Plan
 - Verification Information Sheets



In Conclusion...

- HE System team has been key to ensuring
 - Human is treated as a “system” with key functions, requirements, and interfaces to vehicle systems
 - HE is involved early in the design process
- The low-fidelity mock-up evaluations along with human modeling analysis generated discussions that:
 - led to high-level systems requirements and human-centered design decisions
 - Habitable volume is a key enabler of the human system’s ability to meet its requirements safely, and effectively accomplish mission goals
 - allowed HE requirements and operational concepts to evolve in parallel with engineering system concepts and design requirements
 - Habitable volume should be managed as an integrated system (considering stowage, equipment, and fixed and reconfigurable vehicle structures)
 - Translation corridors within the habitable volume must be established to reduce crew risk during a contingency such as pad egress, fire or off-nominal landing

BOTTOM LINE: Continued HE involvement will ensure a structured approach to human-centered CEV design.



THANK YOU!

